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The Value Assessment Method for Evaluating Preventive Maintenance Activities

by
James H. Johnson

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The objective of this research was to develop a standard method to help maintenance managers at military installations determine the relative value and cost-effectiveness of PM activities. Information gathered by surveys and site visits was used to create a foundation for selecting and performing PM tasks. This foundation, the Value Assessment Method, was then used to develop a method for defining the value (or importance) of a PM activity based on the mission and the cost-effectiveness of the activity.

The automated system proposed by this report will be adapted and programmed as a module in a commercial package (MAXIMO by PSDI). If field tests are successful, an upgraded version will be provided to the U.S. Army Engineering and Housing Support Center for distribution to Directorates of Engineering and Housing.

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James H. Johnson

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FOREWORD

This research was conducted for the U.S. Army Engineering and Housing Support Center (EHSC) under Interagency Order (IAO) E878-80261, dated September 1988. The EHSC technical monitor was Mike Smith (CEHSC-FB-S).

The work was performed by the Facility Systems Division (FS), U.S. Army Construction Engineering Research Laboratory (USACERL). The principal investigator was James Johnson. Assistance was provided by Michael Shamsie, with contributions by Robert Neathammer, Don Hicks, and John Williamson. Dr. Michael J. O'Connor is Chief of USACERL-FS. The USACERL technical editor was Gloria J. Wienke, Information Management Office.

COL Everett R. Thomas is Commander and Director of USACERL, and Dr. L.R. Shaffer is Technical Director.

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1 INTRODUCTION

Background

Because the advantages of preventive maintenance (PM) are difficult to quantify and the returns are often seen only in the long term, PM operations are subject to frequent economic reviews. Maintenance managers in Army installation Directorates of Engineering and Housing (DEHs) need effective methods to defend PM activities because short-term funding limitations could lead to reduced PM and the long-term effects could be very costly. Since the cost of maintaining an asset can often exceed its purchase price, PM managers must obtain the best return for the maintenance dollar. An effective, low-cost maintenance program is based on a practical cost benefit balance between scheduled (preventive) and repair maintenance. To best achieve this balance, maintenance managers need both technical and cost data on each maintained unit (equipment, system, or component of a facility).

Objective

The objective of this research was to develop a standard method to help maintenance managers at military installations determine the relative value and cost-effectiveness of PM activities.

Approach

The first step in this study was to mail a survey to several installations that have diverse PM activities. The researcher then visited installations to verify and expand on the data provided. Based on the survey responses and site visits, the researcher created a foundation for selecting and performing PM tasks. Using this foundation, the researcher then developed a concept for automating data collection and storage and defining the value (or importance) of a PM activity based on the mission and the cost effectiveness of the activity.

Scope

This research was directed at evaluating individual PM activities; an overall evaluation of the total PM program was not attempted.

Mode of Technology Transfer

The automated system proposed by the report will be adapted and programmed as a module in a commercial package (MAXIMO by PSDI). The complete software package is to be tested at the Madigan Army Medical Center, Fort Lewis, WA. If test results are good, an upgraded version will be provided to the U.S. Army Engineering and Housing Support Center for distribution to DEHs.

2 PM MANAGEMENT REVIEW

Management Methods

PM management practices are based on priorities, the availability of human and financial resources, and technical data on the unit being maintained. When developing priorities, maintenance managers should recognize that the reasons for keeping a PM task on the shop's work roster are different from the reasons for scheduling a PM task. The PM work roster is based on the value of a task to the installation and on the cost effectiveness of that task, whereas PM scheduling relates to the timeliness and coordination of a task.

Survey and site visit data were organized into a list (Appendix A) according to the PM categories listed in Table 1. Although PM tasks related to medical facilities, mission support, and utility plants/distribution systems are mandatory and may be removed only by a command decision, they are included to present a total PM picture. Tasks in the other categories are affected by local decisions.

Scheduling

Effective maintenance scheduling requires knowledge of priorities and available resources. Operating systems may need immediate, continuing, or intermittent inspection/servicing. Thus, PM scheduling may be fixed (must be performed at a specific time), variable (required, but with some flexibility in the time of performance), or optional (desired, but may be skipped without immediate consequences). The PM categories are grouped in Table 2 by the order in which the PM tasks should be scheduled. Scheduling is accomplished by comparing the available resources with a listing of the total maintenance workload that is detailed to a prioritized task level.

Table 1

Categories of Preventive Maintenance at Military Installations

Category	Activity
A	Hospitals and emergency medical facilities
B	Installation-mission support
C	Utility generating system
D	Utility distribution system
E	Base safety/protection systems
F	Sewage system
G	Medical/dental outpatient clinics
H	Base services support
I	Domicile/housing support
J	Building habitability and structural systems
K	Waste collection and processing systems

Table 2

Scheduling Priorities of PM Activities

Category	Activity
	FIXED SCHEDULE (Prescribed time PM inspections/servicing)
A	HOSPITALS -life support equipment -monitoring/servicing systems -patient service systems
B	MISSION SUPPORT -communication/computer or mission-control centers -monitoring/environmental-control systems
C	UTILITY PLANTS -inspection/servicing of operating units -check of instrumentation readings
F	SEWAGE SYSTEM -sewage plant (operation and equipment checks)
	VARIABLE SCHEDULE (Flexible time PM inspections/servicing)
E	BASE SAFETY/PROTECTION SYSTEMS (Not usually a PM Shop responsibility) -police/base-security call systems -fire alarm box inspections -fire hydrants and their water supply system
G	MEDICAL/DENTAL CLINICS -examination room utilities -building services
H	BASE COMMISSARY SERVICES -perishable food storage and preparation equipment -monitoring/control systems
I	DOMICILE/HOUSING SUPPORT
B	MISSION SUPPORT STRUCTURES -command facilities -materials handling and storage facilities
D	UTILITY DISTRIBUTION SYSTEMS -water system (pumps/valves servicing) -electrical system (substations/power-lines) -gas system (pressure checks/valves/leak-tests) -centralized steam supply (P/T/%Sat/heat or vapor loss)

Table 2 (Cont'd)

Category	Activity
A	HOSPITAL -auxiliary and habitability systems
F	EXTERNAL SEWAGE SYSTEM INSPECTIONS -pipe line feeders and trunks
	OPTIONAL SCHEDULING <u>(Convenience PM servicing/inspections)</u>
H	BASE SERVICES BUILDING/SYSTEMS SUPPORT -communications, habitability, and auxiliary systems
I	BUILDING HABITABILITY SYSTEMS -internal utilities distribution -plumbing systems forced air systems -other
J	BUILDING STRUCTURAL SYSTEMS -weathering inspections -structural members -floors/ceilings/stairs/roofing -others
K	WASTE COLLECTION SYSTEMS -trash collection and disposal system (burial/burning/recycling) -base drainage system (integrity/outflow inspections)
	PM OVERHAUL SCHEDULING <u>(Does not include breakdown repairs and overhauls)</u>
	AIR CONDITIONING AND REFRIGERATION SHOP -HVAC overhauled in winter -heating systems overhauled in summer
	HYDRAULICS SHOP -minor pump overhaul (repack bearings) -major pump overhaul (rebuild)

Data Collection

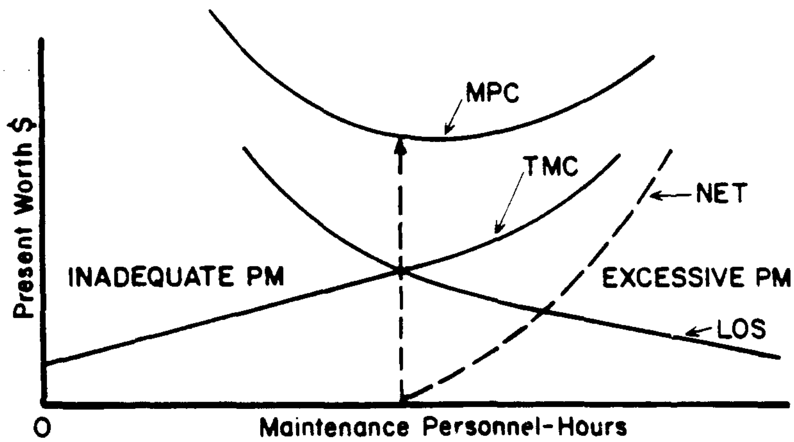
Collecting and interpreting maintenance data is one key to effective PM management. Although it is easiest to collect maintenance data each time PM is completed, maintenance histories can be built from operation records. The history for each unit should include the installation date and inspection/maintenance/repair records. The type and cost of replaced parts and the proposed maintenance schedule should also be recorded.

Figure 1 shows an "optimum" level of maintenance for either a specific system or an entire organization. Because it is difficult to obtain the quantitative information needed to create such a plot, managers can develop averages based on local information, and apply the averages to this plot. Figure 1 assumes a fixed quality of maintenance. The optimum operating point can be improved either by minimizing the Loss Of Service (LOS) cost or by reducing the total maintenance costs (TMC). LOS is the unit cost of not providing full maintenance plus the allocated costs of a higher rate of total system downtime and lowered customer good will. For an assessment to be meaningful, the LOS estimate must be held to reasonable values. The present worth LOS cost for a critical unit, generally, should not exceed the cost of installing a standby for that unit.

Maintaining maintenance histories is made easier by microcomputers now available to most PM managers and by a broad Army wide data base known as the Integrated Facilities Systems for Mini/Microcomputers (IFS-M). An automated data system can also help during scheduling of limited personnel resources by comparing a list of the maintenance needs to a prioritized task list. An automated system also provides a data base for easy input or recall of the maintenance history for each unit serviced. Data base requirements for a typical installation are shown in Appendix B.

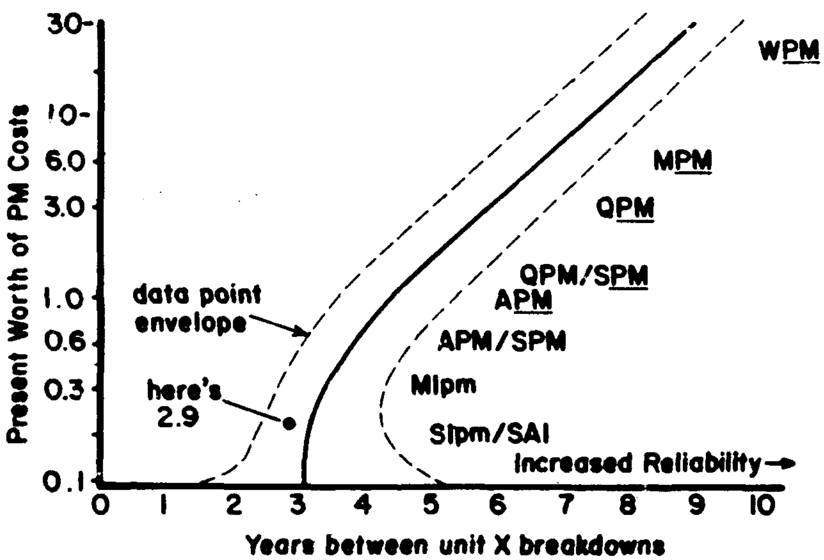
Figure 2 shows the incidence of failure and/or prescribed major overhaul for varying rates of applied PM as recorded for a fictitious unit X. All failure rate experience with the type of unit being investigated should fall within the data point envelope shown by the dashed lines. PM levels (denoted by abbreviations) are labeled by the envelope from negligible (SAI) to extensive (M/W PM), moving up the graph. For rudimentary PM and semiannual inspections, the mean time between failure ranges from 2 to 5, with a median of about 3.2. The narrower the data envelope, the more confidence can be placed in the correlation between PM and mean time between failure. The average of the data points (shown as a solid line) represents the best correlation between PM and failure rates. This type of analysis would help PM managers predict the effect of funding constraints on failure rates.

At most DEHs, the effect of PM on failure rates is not known precisely, if at all. PM economic studies generally rely on sketchy historical data, shop expertise, and averaged data from literature. Even so, an organized analysis using available data will be more accurate and more persuasive than "eyeballing."



TMC:	Total Maintenance Costs (expenditures).
LOS:	Loss of Service Cost (unit cost of not providing full maintenance plus the allocated costs of a higher rate total system downtime and lowered customer good will).
NET:	NET cost of maintenance = TMC + LOS.
MPC:	Maintenance Program Cost = TMC + LOS. (This is the total operations cost that is due to the level of maintenance perf.rmed.)

Figure 1. The optimum level of maintenance performance.



SAI: Semiannual Inspections
S/M Ipm: Semiannual/Monthly Insp and Rudimentary PM
A/S/Q PM: Annual/Semiannual/Quarterly, basic PM
A/S/Q PM: Annual/Semiannual/Qu.rterly, full PM
M/W PM: Monthly/Weekly full PM

Figure 2. Correlation of PM level and elapsed time (years) before unit failure.

3 COST BENEFIT ANALYSIS

Graphs

The benefits of a PM program are the net savings gained by performing PM on a particular unit over not performing the PM. The cost benefit balance is the difference between what is spent on the unit and the value received back from the unit. Determining these elements requires reliable maintenance and failure-rate data collected over time. Managers can then define trends that can be used to estimate changes in cost relationships and to extend the life of the unit.

To gain a good understanding of the short- and long-term justifications for unit maintenance, PM managers should prepare generalized cost benefit graphs. A graph such as that in Figure 3 shows the difference between performing PM at a specified level or not performing any PM, which requires paying the future costs for failure/repair or major overhaul. This type of approach can be useful even when only minimal data is available. Figure 4 uses the approach of Figure 3 to develop an actual cost justification graph for any unit PM over a 10-year review cycle. This graph approximates PM cost relationships as derived in Appendix C. Figure 5 is an expanded version of the lower values on the graph in Figure 4.

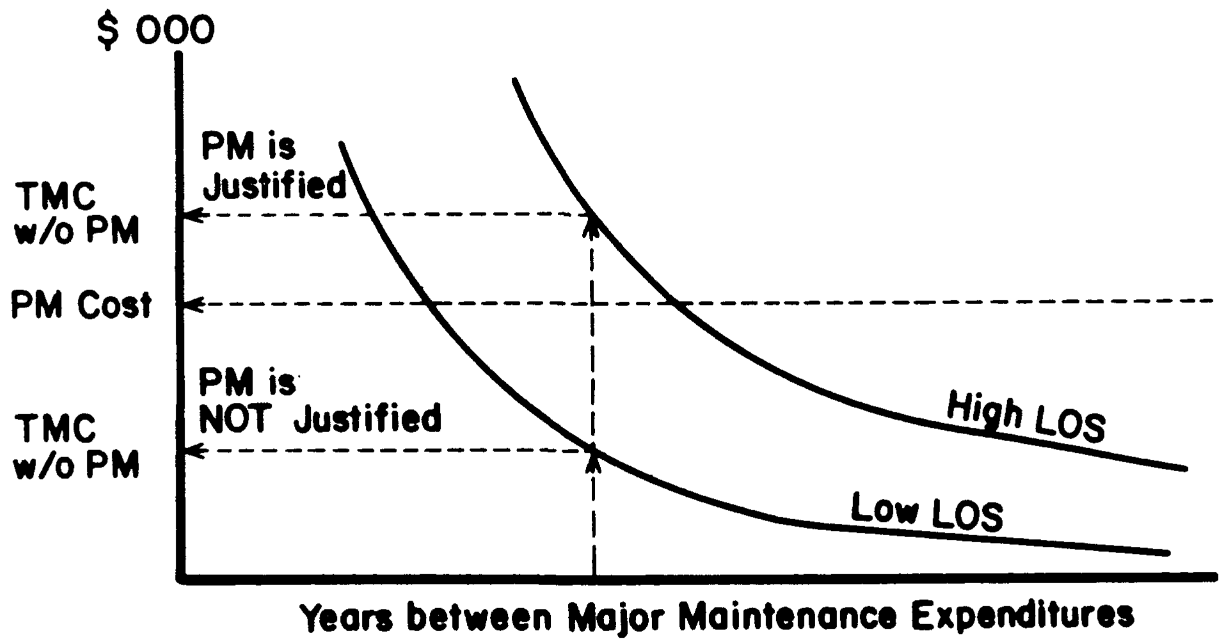
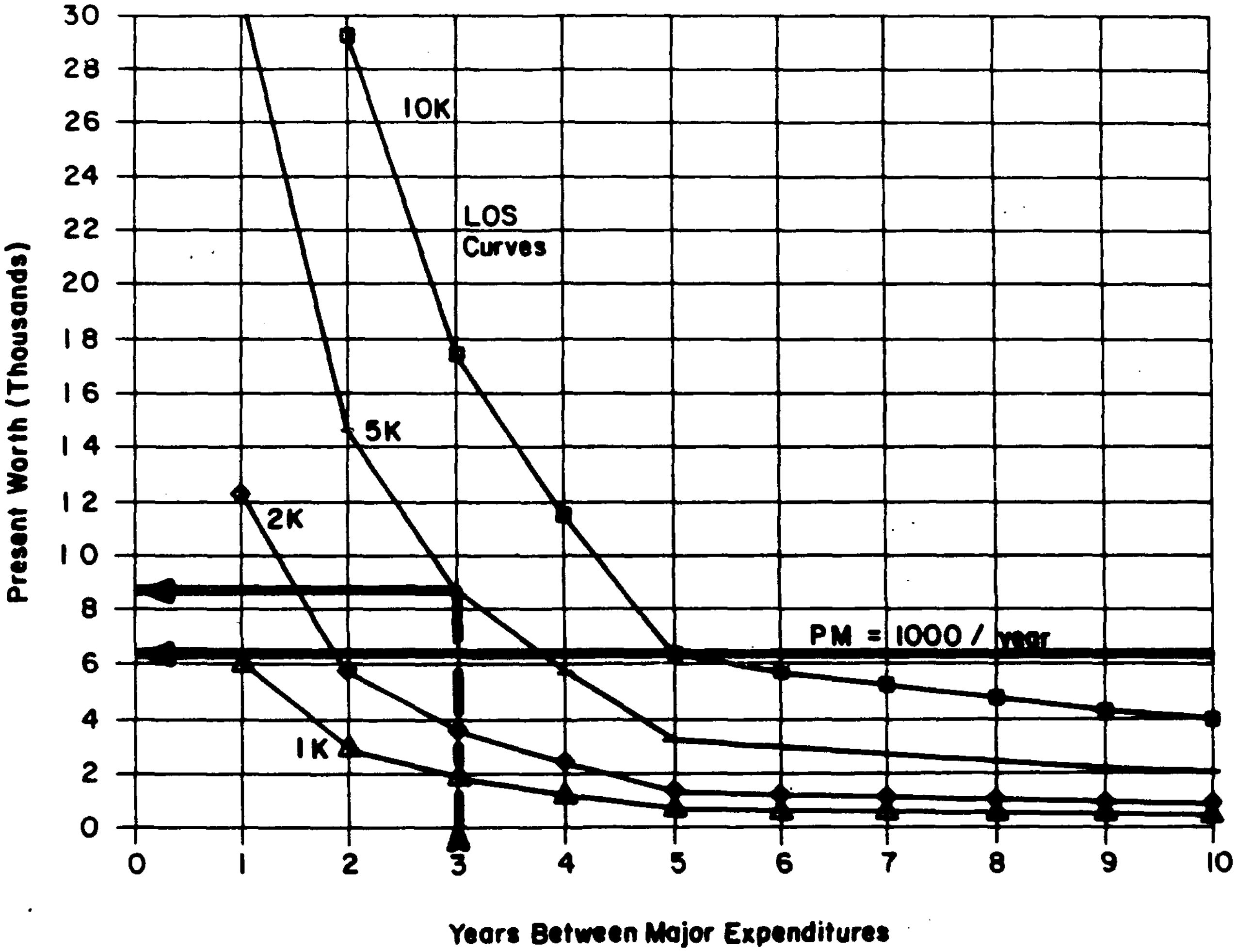


Figure 3. Regions of PM cost justification.



LOS: Total Loss Of Service charges including Major Repair/Overhaul expense + loss of the UNIT's operation + etc., for one scheduled downtime.

PM: Preventive Maintenance at a specified cost level.

Figure 4. Relationship of maintenance cost vs years between major expenditures.

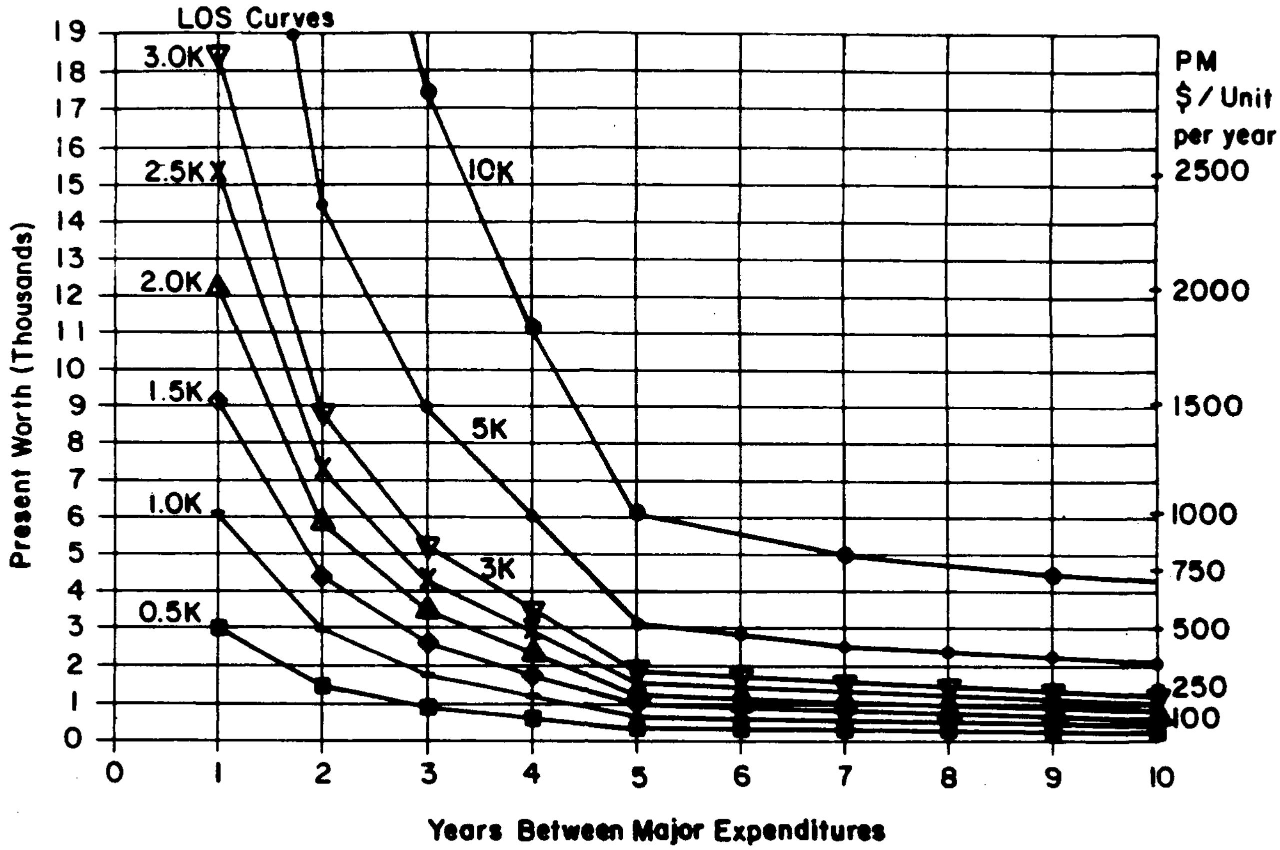


Figure 5. Detail of lower values for Figure 4.

Examples

The following paragraphs contain examples of the cost benefit analysis. The solution to the first problem is based on an approximation derived from Figure 4. The solution to the second problem presents three scenarios based on a more exact analysis.

Problem

The validity of spending PM funds on unit X is questioned. After ensuring that the PM applied to unit X is technically effective and efficient, PM management wishes to estimate the cost benefit of performing PM.

Assumptions

1. Unit X has PM performed at a net cost of $1000/year.
2. Statistically, unit X can be in service for 10 years without a cost-significant breakdown.
3. Historical data indicate that without PM, unit X will fail or have a major repair every 3 years.
4. For every failure of unit X, the LOS penalty is estimated by a knowledgable DEH analyst to be $5000.

Solution

Apply Figure 4 as follows:

1. On the X-axis, find the vertical line for 3 years between major expenditures.

2. Move up this line to the horizontal line corresponding to a PM of $1000/yr; read the 10-year present worth of this PM on the Y-axis, which is approximately $6140.

3. Continue up the 3-year line to the LOS = 5K curve; note that the present worth of LOS (for more than 3 failures over 10 years) on the Y-axis is approximately $8800.

4. To get an approximate cost benefit for unit X PM, subtract the PM present worth of step 2 from the LOS present worth of step 3: $8800 - $6140 = $2660.

The cost benefit of performing PM at $1000/yr is $2660 for this unit over a 10-year period.

Problem

Quantitatively compare three PM scenarios (Case 1: Full PM; Case 2: Nominal PM; Case 3: No PM) for an accessible deep-well, motor driven pump. Here the PM cost estimation graphs are not applicable and detail computations must be used. Basic charges are as follows:

1. In each case, the pump and drive can be bought and installed for approximately $25,000. If the pump should break down, the repair charges will be approximately $5000. A $2000 downtime charge is assessed for any unscheduled repairs. Scheduled repairs and overhauls cost the same as unscheduled repairs, but can be performed on weekends for $1000 (overtime plus other expenses).

2. Full PM and associated PM inspections are performed at a cost of $300/year with a $75 increase every 5 years because of system aging. Nominal PM and PM inspections can be performed at $120/year without increase.

Assumptions

1. Either system removal and sales cost always equal salvage return, or salvage is not a factor.
2. Interest is constant at 10 percent; future purchase inflation is balanced by money charges.
3. The system will last for at least 20 years with full PM services, experiencing only one overhaul in the last 10 years of its projected life (Case 1).
4. The system will last for at least 15 years with nominal PM (inspections) and one major overhaul (Case 2).
5. The system will last for at least 10 years with no PM and one breakdown (Case 3).

Solution

Computations of Appendix D provide the following results:

CASE 1: Full PM, 20-year life, a 20-year study period.

0	5	10	15	20
25K			repair (5K) downtime (2K)	removal

PM @ \$300/yr with \$75/yr increments every 5 years.

Initial Outlay:	\$25,000
Present Worth (PM):	3,153
Present Worth (Overhaul):	1,675
TOTAL	\$29,828

CASE 2: Nominal PM, 15-year life with a 5-year prorated replacement, a 20-year study period.

0	5	10	15	20
25K	overhaul (5K) + overtime (1K)		allocated costs of unit replacement & future overhaul (13.3K)	

PM (inspections) @ \$120/yr for 20 years.

Initial Outlay:	\$25,000
Present Worth (PM):	1,022
Present Worth (Overhaul):	2,799
PW(13.3K):	3,184
TOTAL	\$32,005

CASE 3: No PM, 10-yr life with replacement, a 20-yr study period.

0	5	10	15	20
25K	repair (5K) + downtime (2K)	replacement (32.5K) + overtime (1.0K)	repair (5K) + downtime (2K)	removal

Initial Outlay:	\$25,000
Present Worth (Repair 1):	4,345
Present Worth (Replacement):	12,916
Present Worth (Repair 2):	1,676
TOTAL	\$43,937

4 THE VALUE ASSESSMENT METHOD

The PM Value Assessment Method as described in this chapter can be used to justify specific PM activities and/or to determine the least damaging workload deletions under mandated budget cuts. It allows a prompt response to general or specific PM inquiries. The relative values of PM activities are not fixed and can change with DEH redirection, with modifications to or the phaseout of supported systems, and with changes in the needs of the installation. The dynamic methods indicated are well within the capabilities of commercially available data base packages. Furthermore, because the same data base will be used and updated with inspector and PM technician daily reports, the technical and cost data will always be current.

Ordered PM Listings

To be successful, the PM lists must be generated and applied according to locally determined values and constraints. When local PM management appraises the PM workload, they can make adjustments for the many influences and factors specific to the installation.

Ordered PM Category List

The basic list in the Value Assessment Method is the Ordered PM Category List, which groups all PM categories into four priority classes:

1. Mission and safety (M/S) PM categories are MUST,
2. Non-M/S categories that are functionally essential to base operations are REQUIRED,
3. Non-M/S categories that are not essential but contribute to functional and efficient base operations are NEEDED, and
4. Other PM categories are MARGINAL.

General PM List

The General PM List potentially includes systems/units from all PM categories, and by implication, all of the associated PM tasks. This list is grouped in the order of Table 1, and is built up as follows:

1. The associated systems/equipment supported under each category or unit are identified and listed,
2. All PM tasks associated with each unit (belonging to a parent system in a specific PM category) are then included, and
3. Priority and cost-effectiveness are then included as attributes of each PM task.

Preferred PM Task List

One spinoff from the General PM List is a Preferred PM Task List, showing an absolute priority ladder for every PM task performed at the installation. The Preferred PM Task List is generated by reordering tasks on the General PM List. For tasks at the same level, use their cost benefit balance and then the level of the parent category to determine their order. In the unlikely event that two tasks have the same cost-effectiveness and parent level, use decreasing assignable workhours to determine the order.

For a completed Preferred PM task List, every PM Task will have a unique position or sequence number which becomes a part of its label.

Preferred PM Category and Task List

Another spinoff is a Preferred PM Category and Task List. This list is identical to the General PM List except that the PM tasks are grouped under a parent (or shop) category in order of the sequence number on the Preferred PM Task List. It can be generated as a modification of the General PM List of Appendix A for the convenience of PM management planning.

Processing the General PM List

The continuing development and upgrading of the General PM List is fundamental to the Value Assessment Method. If the spinoff reports are to be accurate, the General PM List should be on line to an active PM data base.

1. For each PM task applied to a unit on the General PM List, determine the standard craft-hours, the equipment and material charges involved, and the estimated magnitude of the task's cost-effectiveness. The first two are obtained according to standard DEH practices and the last by procedures of Chapter 3.

2. Develop and record a "priority label" for each PM task as follows:
   a. Determine if the PM task is MUST:
      - it is feasible to perform.
      - it is essential to maintaining the unit.
      - the unit is essential to a MUST PM Category.
   b. Determine if the PM task is REQUIRED:
      - it is feasible to perform.
      - it is cost-effective to perform.
      - it is essential/important to maintaining the unit.
      - the unit is essential/important to a REQUIRED/MUST PM Category.
   c. Determine if the PM task is NEEDED:
      - it is as in b., but it is marginally cost-effective.
        (OR)
      - it is feasible.
      - it is cost-effective.
      - it is important/helpful in maintaining the unit.
      - the unit is important/contributory/helpful to a NEEDED/REQUIRED/MUST PM Category.
   d. Determine if the PM task is MARGINAL:
      - it is as in b., but it is difficult to perform.
        (OR)
      - the unit is in a REQUIRED Category; PM Task is feasible, but is marginally cost effective.
        (OR)
      - it is feasible.
      - it is cost effective
      - the unit is important/contributory to a NEEDED/REQUIRED PM Category.

Even using an automated system, it is still necessary to understand the above logic in order to have confidence in the labeling of the PM tasks.

Example

Problem

Develop a Preferred PM Task List.

Assumptions

Assume that a particular installation is supported by a DEH with a PM Shop that has an established expertise in air compressors/blowers and air conditioners. All other PM is performed by other shops or is contracted. Also assume that maintenance management wishes to create an ordered list of the PM tasks on the performance roster of this PM Shop. The PM tasks are taken from the General PM List previously developed for the installation. (The list is similar to that provided in Appendix A.)

Procedure

If the PM Task List is created manually, an interim list of applicable PM jobs or tasks is taken from the General PM List, and left in the same order. Further, if the interim list is annotated to assess each PM task according to the evaluation system previously outlined, a MUST, REQUIRED, NEEDED, or MARGINAL rating for each job/task in the PM Shop can be developed. Table 3 provides the complete interim list for the PM Shop.

CAUTION: Table 3 does not imply scheduling preferences. It reflects only the relative value of the PM job/tasks to the maintenance mission. The process does not judge retention of the unit, but the value of the PM supporting the unit. Cost effectiveness is not a factor in determining a MUST label for a PM task, but it is an important factor for all lesser labels.

By grouping tasks under their appropriate ratings in the sequence that they are processed, a Preferred PM Task List for the PM Shop will be obtained (Table 4). This process can be repeated to get the PM activities ordered to the subtask level, if needed.

Automated Analytical Support

The Value Assessment Method can be programmed into a total PM Management System that can output various budgetary products. To identify the effect of budgetary reductions on PM, equivalent PM workhours allowed by the new budget can be determined. The workhours are then summed top-to-bottom in the PM Task List until the materials and personnel charges are exhausted. The "drop line" for the proposed budget is then drawn at that point, and the criticality of the reduction may be assessed.

An acceptable PM management software system will generate needed PM operations and task evaluation reports. A PM Task Justification report will justify a particular PM task according to the performance history for the task/unit. It will include PM Task labeling and a cost-effectiveness computation. A PM Program/Category Justification report justifies the entire PM program or a PM category. The sum of the cost benefits are determined for all PM categories (from each PM task making up the category), and these category sums are then summed for the total PM Program.

Table 3

Interim PM Task Preference List

Category/Unit	Label
A. **HOSPITALS** Not Available	
B. **COMMAND AND CONTROL FACILITIES**	
3. ENVIRONMENTAL CONTROL, MISSION AREAS	
b. Humidifiers	MUST
c. HVAC Systems	MUST
C. **G/P PLANTS**	
1. Steam Plant (SP)	
b. Forced Air Blowers (FAB)	
(for boiler furnace)	MUST
- blower unit	MUST
- duct/injection system	MUST
3. Sewage Plant	
b. Blower Sys, Grit Area	MARGINAL
c. Blowers, Sludge and Scum Rooms	NEEDED
f. Compressed Air Supply System (CAS)	REQUIRED
- air compressor	REQUIRED
- storage tank and distr	REQUIRED
D. **M/D CLINICS**	
1. Emergency/Patient Room Systems	
b. Pressurized Gas Systems	MUST
E. **UTILITY DISTRIBUTION SYSTEMS**	
None	
F. **FIRE AND SECURITY PROTECTION**	
N/A	
G. **COMMISSARY FACILITIES**	
1. Cold Storage Plant	
a. Room/Locker Refrigeration Systems	MUST
2. Equipment and Appliances	
a. Kitchen Equipment	
- heat/smoke vents	REQUIRED
- ice cream makers	NEEDED
b. Ice Machine	NEEDED
c. Refrigerators/Freezers	NEEDED
- reach-in	REQUIRED
- walk-in	REQUIRED
d. Air Dryer Equipment	NEEDED

Table 3 (Cont'd)

Category/Unit	Label
H. POL/VEHICLE CENTERS	
1. POL Center	
a. Air Compressors	NEEDED
2. Vehicle Center	
a. Air Compressors	REQUIRED
I. SERVICE BUILDINGS (SBs)	
2. SB Components	
b. Roof/Ceiling Components	
- ventilators and ducts	NEEDED
3. SB Utilities	
b. SB Appliances	
- AC	REQUIRED
- Ice Machines	MARGINAL
- Refrigeration Equipment	REQUIRED
J. BUILDINGS, QUARTERS, AND HOUSING	
3. Habitability Systems	
a. Air Conditioners	REQUIRED
- AC, package	NEEDED
- AC, window	NEEDED
c. Appliances	
- ice machines	MARGINAL
- refrigerators	REQUIRED

Table 4

Sample Preferred PM Task List for an Example PM Shop

MUST	REQUIRED	NEEDED	MARGINAL
B.3.c: HVAC System	C.3.f: CAS System	C.3.c: Blowers, Sludge and scum	C.3.b: Blowers, Grit Area
C.1.b: FAB System	H.2.a: Vehic Ctr-Air Compr	G.2.a: Kitch Equip-Ice Cream Makers	G.2.a: KEq-vents (not cost-effective)
G.1.a: Room/Locker Refrig Systems	I.3.b: SB Appl-Air Cond	G.2.c: KEq-refr/frz	I.3.b: Ice Machines
	J.3.a: Hab Syst-Air Cond	H.1.a: POL-Air Compr	J.3.c: Ice Machines
	J.3.c: Hab Syst-Refrigerators	I.2.b: Roof-Vents/Ducts	

5 CONCLUSIONS AND RECOMMENDATION

Conclusions

The Value Assessment Method developed during this research can help maintenance managers at military installations determine the relative value and cost-effectiveness of PM activities. To use the Value Assessment Method, managers need maintenance and failure-rate data to define trends needed to estimate changes in cost relationships. Moreover, managers need to establish PM category and task lists, define scheduling demands, and collect a maintenance history for each maintained unit. Because the incidence of failure relates to the level and the cost of PM, managers can need create cost benefit graphs that predict the time of cost-effective unit replacement.

Recommendation

It is recommended that the automation concept proposed by this report be developed into a prototype program and, if successful, be finalized for general distribution to DEHs.

APPENDIX A:

A GENERAL LIST OF PM CANDIDATES FOR TYPICAL ARMY INSTALLATIONS

C - Fort McCoy
G - Fort Gillem
K - Fort McClellan
L - Fort Lee
M - Fort McPherson
O - Fort Ord

S - Impacts OSHA regulations

MIS - Impacts base mission

E - PM value based on cost savings

I - Inspection
I&A - Inspect & Test/Adjust/Service
I&R - Inspect & Repair/Replace
d/w/m - daily/weekly/monthly
q/ba/an - quarterly/biannually/annually

For example: w, I&R (M) would mean a weekly inspection at Fort McPherson with repair or replacement.

A. HOSPITALS

Not supplied.

B. INSTALLATION-MISSION SUPPORT

1. COMMAND & CONTROL FACILITIES

a. BUILDING UTILITIES
(1) Fail-Safe Support Systems — MIS
- C3 Systems support
- communications center(s) power supplies
- computer/ADP center(s) power supplies

(2) Electrical Back-up Systems — MIS
- aux. lighting, m I (K)
- emerg elect generators, weekly maintenance (K)

b. BUILDING SECURITY
(1) Entry Control — MIS
- unauthorized-entry alarms
- remote control door-lock system
- combination door-locks

(2) Monitor System(s)	MIS
- video monitor panel(s)	
- video cameras & az motors	
- power supply & cabling	
c. ENVIRONMENTAL CONTROL, MISSION AREAS	
(1) Heating Sources	MIS
- Furnace (L)	
-- gas fired	
-- oil fired	
-- oil/gas fired	
- Central Steam Supply	
(2) Humidifiers (PM humidifiers (L)	E
(3) High Volume Air Conditioners (HVAC)	MIS/S
- Startup/Shutdown and PM of AC Plants, (M) and (K)	
- Compressors	
- Air handlers	S
-- 50T (M) TO > 100T, an/q, I&R (M)	
-- Fan coil unit, I&R (M)	S
- Evaporative Condensers, I&A (M)	
-- necessary chemicals, I (G)	S
d. BUILDING ACCESSORIES	
(1) ADP/Computer Auxiliary System	MIS
(2) Elevators & Lifts - QA of contracted servicing (L)	S
(3) Water Heaters	E/S
(4) Habitability Systems	E
e. BUILDING STRUCTURE	S
(1) Foundations	
(2) Basics	
- Walls/Columns	
- Floors, ceilings, stairs	
- Roof & roof-support structure	

C. UTILITY GENERATING PLANTS

1. <u>STEAM PLANTS</u>

a. TYPES	
(1) Power Plant, HP Boilers (160 to 208),	
- PM for HP steam plants (M)	S
- assist in contractor's inspection (L)	
(2) Heating Plant, LP Boilers	
- PM performed for heating plants (L)	
- PM performed for 185 LPB systems (K)	

b. OPERATING COMPONENTS

(1) Steam Generation Control Panel — S
- flow/quality data, water to steam, I&A
- furnace control, adj air/fuel mix, I

(2) Automatic Control System — E/S
- measurements feedback, I
- adaptive control unit(s), I&A
- actuators, I

(3) Furnace Forced Air Systems — E/S
- blower controls, I&A
- blower units, I

(4) Furnace Fuel-Oil Supply System — E/S
- fuel-oil pump(s), I&R (L)
- fuel-oil storage

(5) Furnace Firebox — E/S
- PM/clean furnace(s) (K)

(6) Feed Water System — E/S
- hot water storage tanks, I (M)
- heat exchangers, I&R (M)
- oil/water separator
- feed water additive system
- feed water pumps
- on-line deaerator

(7) Boiler Drum Unit — E/S
- firebox/tubes
- pressure regulators
- relief-valves/blow-down systems
- monitoring systems

(8) Steam/Water Lines and Pits — E
- PM of steam mains & pits (K)
- PM of high temp water lines & pits (K)

(9) Evaporative Condensers/water, I (G) — E

(10) Condensate/Sump Pumps, I&R (M) — E
- inspections (lube levels; bearings; seals)
- line valves periodic rotation
- clean strainers/filters
- check alignments, gear box operations
- driver system checkout

(11) Cooling Towers — E

(12) Furnace Effluent Controls — S
- particle separators, I
- bags, filters, etc., I

2. <u>WATER TREATMENT PLANT (WTP)</u>
PM PROCEDURE FOR A WTP (M) (K)

a. AUTOMATED WTP CONTROL SYSTEM — E/S
[maintenance of ACS (L)]
(1) control panel
(2) automated system
(3) actuators

b. DEEP WELL PUMP SYSTEM

(1) Pump Housing(s)	E
- check vents (O)	
- check gravel pack (O)	
- paint metal housing (if needed)	
(2) Deep Well Pump (DWP)	MIS
- check pump gaskets/seals (if accessible)	
- grease the check-valve (O)	
- check/lube flow meters (O)	
(3) DWP Engine Operation, tested under load for	MIS
- engine fuel levels	
- water drawdown levels (O)	
- safe pump yields (O)	
(4) Motor Driven Blower	E
- check belt tension (O)	
- check pulley alignment (O)	
- check elec motor oil level (O)	
- lube motor bearings (O)	
- paint exposed metal parts	

c. BOOSTER PUMP SYSTEM

(1) Booster Pump (BP)	MIS
- inspections (oil levels; bearings; seals)	
- lube BP bearings, couplings, check-valves	
- periodic rotation of manifold/line valves	
- clean strainers/filters	
(2) BP Driver	MIS
- check alignments, gear box operations	
- driver checkout, lube motor bearings	
(3) BP Flow and Flow-Control Values	E
- clean & lube pilot and altitude valves (O)	
- operate gate valves (O)	
- lube gate valve stem	
- replace valve packing as needed (O)	
(4) BP Instrumentation	E/S
- clean/service/calibrate water meters and recorders (O)	

d. WATER PROCESSING SYSTEMS

(1) Water Filters, I&A (G)	S
(2) Water Chlorination System	S
- check area vents (O)	
- clean cabinets/working parts (O)	
- clean strainer; inspect ejector (O)	
- service Cl cylinders (L)	
(3) Aerators, Spray Ponds, etc.	S

e. FLOW MANAGEMENT/CONTROL

(1) Control Panel	E
(2) Pneumatic Control System	E
(3) Remote Valve Actuators	E

f. INTERNAL DISTRIBUTION & STORAGE SYSTEM

(1) Flow Valves	E
- operate gate and butterfly valves	
- lube gate valve stem	
(2) Special Valves	E
- clean trap and strainer (auto diapm valve)	
- clean and lube pilot and altitude valves	
- check float valves	

3. <u>ELECTRICAL POWER SUPPLY</u>
(PM for power plant equipment (L6))

a. SOURCE

(1) Standby/Emergency Generators, I&A (M)	MIS
(2) Power Generation Control Systems	S
- electric control panels, I&A (M)	
- electronic sensors (M)	
- pneumatic actuators/switches, I&A (M)	
(3) Power Plant Equipment	E
- clean/test circuit breakers (L)	

b. DISTRIBUTION SYSTEMS (DS)

(1) Main Substation	MIS/S
- inspection daily (K)	
(2) Substations, I (G)	S
- overhead distribution, I (M)	
- transformers [inspect PCB transformers/capacitors (L) and (K)]	S
(3) Overhead DS (Poles, etc), I (M)	S
- insulators (annual cleaning)	
- transformer, pole mtd, I (M)	
- transformer, pad mtd, semiannually	
(4) Underground DS, I&R (M)	S
- concrete cableways	
- buried cables	

D. EXTERNAL UTILITY-DISTRIBUTION SYSTEMS

1. <u>WATER/STEAM DISTRIBUTION</u>	MIS
PM of Water Distribution System (K)	

a. WATER PRESSURIZATION SYSTEM

(1) Booster/Pressurization Pumps (As in C2c, WTP Section).	E
(2) Water Reservoir/Tower System (WR/WT)	E/S
- check general condition & structure	
- operate WR/WT float and flow valves	
- check ladder, sway-bracing, roof hatch-locks, and structural soundness	

b. DISTRIBUTION LINES/VALVES

(1) Hot/Cold Water Circulation System, I (M)	E
(2) Water Lines, I (M) & (G)	E/S
- valves and faucets, I&R (L)	
- X-connections, I&R (L)	
- check flow meters	
(3) Steam Lines, I (M)	S

2. <u>NATURAL GAS</u> MIS

a. NATURAL GAS LINES/VALVES S

(1) servicing of NG valves, an I&R (K)
(2) check gate valves and manifold valves
(3) check flow meters

b. NATURAL GAS STORAGE TANKS S

(1) check P/T measurements
(2) check volume indicators

3. <u>ELECTRICAL SYSTEMS (EXTERNAL)</u> MIS

a. INSULATORS AND TRANSFORMERS, POLE MTD, I&R (M) E/S

b. STREET AND AREA LIGHTING, I&R S

4. <u>TELEPHONE LINKS</u>
(Contracted upkeep)

E. BASE SAFETY/PROTECTION SYSTEMS

1. <u>FIRE PROTECTION</u> MIS

a. FIRE HOUSES E/S

(1) Compressors, m/an, I&R (M)
(2) Vehicle Support
(3) Habitability Systems

b. BASE FIRE SUPPORT SYSTEMS E/S

(1) Fire Truck Equipment
(2) Fire Alarm Systems, I (G)
(3) Fire Hydrants, I

2. <u>POLICE PROTECTION</u>
(Responsibility not reported.)

F. SEWAGE SYSTEM

1. <u>SEWAGE PROCESSING PLANT</u> MIS
   PM OF SEWAGE SYSTEM (K)

   a. "BARMINUTOR" (BM) E/S
   (Bar Screen and Comminutor)
   (1) BM Tubes
   - lube tube seals (O)
   (2) BM Cutter/Shear-Bar System
   - check mounting screws (O)
   (3) Reducer Gear
   - check oil levels (O)
   - change gear-housing oil (O)
   (4) Counterweight (Cw)
   - lube Cw shafts (O)
   - oil Cw chains and sprockets (O)
   (5) Bar Screens
   - clean and inspect screens (O)

   b. GRIT CAPTURE SYSTEM E/S
   (1) Blower(s) S
   - check belt alignment (O)
   - check belt tension and wear (O)
   (2) Main Grit Pump (MPG) E
   - MGP bearings and packing gland, clean/lube
   - MGP pulley alignment, I&A (O)
   - MGP belt tension and wear, I&A (O)
   (3) Grit Sump Pump (SPG) E
   - clean SPG pit and the SPG (O)
   - clean the SPG check valve (O)
   (4) Grit Gate Valves (GVG) E
   - operate GVGs (O)
   - lube GVG rising stem threads
   - oil GVG packing
   - change packing (if necessary)
   (5) All Metal Surfaces E
   - paint as needed.

   c. SEWAGE PROCESS SYSTEMS [PRIMARY (PRI) & SECONDARY (SEC)]
   (1) Clarifiers (PRI & SEC) E/S
   - Drive gear reduction unit (GRU)
   -- verify GRU oil levels (O)
   -- grease GRU bearings (O)
   - Scum trough (PRI ONLY)
   -- lube scum trough positioner (O)
   - Turntable and parshall flume (SEC ONLY)
   -- change oil in turntable (O)
   -- wash down parshall flume (O)

- Clarifier tank (CLT)
  - -- drain, flush, and inspect (O)
  - -- CLT equipment, I&A (O)
- Sluice gate (SGC)
  - -- adjust SGC clearance (O)
  - -- perform SGC operations test (O)
  - -- lube fittings and riser stem (O)

(2) Sludge/Scum Processing System E/S

- Sludge pump room - paint metal surfaces (O)
- Blowers - adjust belt tension and pulley alignment (O)
- Main sludge pump (MPS)
  - -- inspect/grease MPS packing glands (O)
  - -- change MPS bearing oil (O)
  - -- lube motor bearings (O)
- Sludge dewatering pump (DPS)
  - -- lube DPS bearings (O)
- Sludge sump pump (SPS)
  - -- clean SPS pit, pump and control valves (O)
  - -- rotate plug valves (O)
  - -- change SPS bearing oil (O)
- Chain hoist - inspect and lube (O)

(3) Scum Pump Room (PRI ONLY) E/S

- Scum pump (SCP)
  - -- grease SCP packing glands (O)
  - -- inspect SCP oil levels (O)
  - -- change SCP oil (O)
  - -- flush/lube motor bearings (O)
- Scum sump pump (SPSC)
  - -- clean SPSC pit, pump and CV (O)
  - -- rotate plug valves (O)
  - -- flush/lube motor bearings (O)

d. FILTRATION AND SCREENING SYSTEMS

(1) Biofilters E/S

- check oil level; replace oil
- check amount of condensation
- adjust distributor arms
- paint metal surfaces

(2) Microscreen System (MS) E/S

- MS control system
  - -- inspect all controls (O)
  - -- inspect solenoid valves (O)
  - -- inspect all control valves (O)
- Pilot valve strainer (PVS) and screen media (SM)
  - -- clean PVS and SM (O)
  - -- inspect pump screens (O)
- Header
  - -- flush the header (O)
- Gear reducer (GR)
  - -- check/change GR oil (O)
  - -- repack GR bearings (O)
  - -- replace grid gasket foam (O)

- MS drum (D)
  - -- inspect D seals/bearings (O)
  - -- lube supporting wheels (O)
  - -- inspect wheel tracks (O)
  - -- check chain slack (O)
  - -- inspect operating spray nozzles (O)
- MS chambers, mixers, and holding tanks (T)
  - -- inspect MS tanks and Cl-contact chambers for solids, flush as needed (O)
  - -- inspect flash mixers (O)
  - -- drain basin; flush basin/screens (O)
- MS gate valves (GVM)
  - -- operate GVM (O)
  - -- lube rising stem threads (O)
  - -- lube GVM packing (O)
  - -- replace packing as needed (O)

e. RECIRCULATION SYSTEMS	S
(1) Recirculation Pump (RP)	E/S
- operate RP pressure switch (O)	
- change RP bearing oil (O)	
- inspect RP check valve (O)	
- change motor bearing oil (O)	
(2) Butterfly Valves	E
- operate and inspect (O)	
(3) Sluice Gate	
- operations test (O)	
f. COMPRESSED AIR SUPPLY	
(1) Air Compressor (AC)	E/S
(2) Intake System	E
- check/clean air cleaner	
(3) Output Supply	E/S
- check the pressure regulator of the AC	
(4) Motor Drive	E
- flush/lube motor bearings (O)	
2. <u>SEWAGE COLLECTION SYSTEM</u>	MIS
a. EXTERNAL SEWAGE LINES, I&R (M) (G)	S
b. SEPTIC TANK SYSTEMS, (Not in survey installations)	S

G. MEDICAL/DENTAL CLINICS

1. <u>EMERGENCY/PATIENT ROOM FACILITIES</u>	E/S

a. ELECTRICAL SYSTEMS
(1) Distribution/Control Panels
(2) Surge Protection Systems
(3) Emergency Generators

b. PRESSURIZED GAS SYSTEMS — S
- (1) Medical Oxygen
- (2) Natural Gas (Heating)
- (3) Pneumatic Systems
  - Control panel
  - Air pressurization source
  - Air pumps
  - Vacuum pumps

c. ENVIRONMENTAL SYSTEMS — S
- (1) Air Conditioning

2. LOCAL LABORATORY SUPPORT

a. MEDICAL SUPPLIES REFRIGERATION — S

H. BASE SERVICES

1. COMMISSARY FACILITIES

a. COLD STORAGE PLANT — S
- (1) Cold Storage Rooms/Lockers — S
  - Refrigeration systems
    - -- liquid chillers, I
    - -- monitor systems, I
    - -- startup/shutdown operations

b. COMMISSARY EQUIPMENT AND APPLIANCES
- (1) Kitchen Equipment, I (M) — E
  - electric mixers/choppers/potato peelers
  - steam kettles and pressure cookers
  - natural gas, microwave and convection ovens
  - electric griddles/skillets/toasters
  - deep fat fryers, I (L)
  - ice cream makers
  - dishwashers
- (2) Ice Machines, I&R (M) — E
- (3) Refrigerators/Freezers, I&R (M) — E/S
  - reach-in
  - walk-in
- (4) Air Compressors, Dryer Equipment, I&R (M) — E/S
- (5) Trash Compactor, I&R (G) — E
- (6) Internal Electric Motor Starters, I&R (M) — E

2. POL/VEHICLE CENTERS

a. LIQUID FUEL LOAD/UNLOAD SYSTEM — S
- (1) control panel/flow meters, I
- (2) fuel pump(s), I&R (G)
- (3) lines/valves/nozzles, I
- (4) underground storage tanks, I (M)
- (5) vehicle scales, I

b. LUBE/FUEL DRUM HANDLING E
   (1) drum scales, I
   (2) hand pump(s), I
   (3) drum cleaning system, I

c. AIR COMPRESSORS (M) S

d. SPILL CLEANUP EQUIPMENT S

e. WASTE DISPOSAL SYSTEM S

3. <u>SERVICE BUILDINGS</u>

a. BUILDING STRUCTURE
   (1) Foundations S
   (2) Basics E/S
      - Walls/columns
      - Floors, ceilings, stairs
      - Roof and roof-support structure

b. BUILDING COMPONENTS
   (1) Doors, Windows, and Walls E/S
      - Entrance/interior doors (secured and unsecured)
         -- wood/metal framed, I (M)
      - Automatic doors
      - Fire doors S
         -- sliding, insulated
         -- overhead, roll-up, I&A (M)
      - Walls and partitions (permanent and temporary)
      - Glazing
   (2) Floor Covers/Finishes and Ceilings E
   (3) Roof/Ceiling Components E
      - Roofing type
         -- built-up
         -- tiled/shingled
      - Gutters and downspouts, I (M)
      - Ventilators and ducts
         -- powered ventilators, I (M)
   (4) Basement Systems E

c. SERVICE BUILDING UTILITIES
   (1) Interior Distribution S
      - Pipelines/valves
         -- hot/cold water circulation system, I (M)
         -- water lines, I&A (M) and (G)
         -- sprinkler systems, I (M)
         -- steam lines, I&A (M)
         -- plumbing system, I&A (M) and (G)
         -- gas lines, I&A (M)
      - Meters, gas/water/electric (reading), I (M)

(2) Service Building Appliances	E/S
- air conditioners	
-- package units, I&R (M) and (G)	
-- window units, I&A (M)	
- refrigeration systems	
-- ice machines, I&R (M)	
-- refrigeration equip, I&R (M)	
- electric motors	
-- internal electric motor starters, I&R (M)	
- fire alarms, I (M)	S

I. DOMICILE/HOUSING SUPPORT

1. <u>BUILDING COMPONENTS</u>

a. STRUCTURAL

b. BUILDING ACCESSORIES	
(1) Elevators and Lifts	S
- QA of contracted servicing (L)	
(2) Secure Door-Lock Systems	S
(3) Habitability Systems	E
(4) Fire Prevention Systems	S
-fire alarms, I (M)	
-sprinkler systems, I (M)	
(5) Ventilators, Powered, I&A (M)	E

2. <u>HABITABILITY SYSTEMS</u>

a. AIR CONDITIONERS	
(1) Package Units, I&R (M) and (G)	S
(2) Window Units, I&R (M)	E
b. FURNACES/HEATERS	
(1) Gas-Fired Furnaces, I&A (M)	S
(2) Gas-Fired Heaters, I&A (G)	S
- GFH startup/shutdown operations and PM (M)	
- heating equipment, I&R (G)	
(3) Gas/Oil-Fired Heaters, I&A (M)	S
(4) Steam/Hot-Water Heaters	
- internal steam/HW lines and radiators, I (M)	
c. APPLIANCES	
(1) Ice Machines, I&R (M)	E
(2) Refrigeration EQ/Comp, I&R (M)	E
(3) Trash Compactor, I&R (G)	E

APPENDIX B:

SAMPLE MAINTENANCE RESOURCE LEVELS NEEDED AT FORT TYPICAL

SIZE/QUANTITY OF PM SUPPORTED SYSTEMS OR UNITS

<u>Water Supply System</u>:	
Water well pump stations	7 Each
Water distribution system/stations/etc. - sprinkler systems	490,082 LF 43 Bldgs
<u>Sanitary System</u>:	
Sewer lines	309,739 LF
<u>Exterior Electric</u>:	
Main substation	1 (daily)
Electric lines	37 areas or 166 miles (semi-an)
PCB transf/capacitors	197 (quarterly)
Other transformers	17 areas (semi-an)
Lightning protection	17 post areas (semi-an)
<u>Steamfitting & Plumbing</u>:	
Natural gas valves, servicing & lubricating	920 valves (yearly)
Boiler systems PM, inspect & test	185 systems/plants
Steam mains and pits	51,866 LF
High temp water lines & pits	15,300 LF
Furnace PM	248 furnaces
Bldg heating equipment PM	386 Bldgs
FH heating, start-up/shut-off PM	571 Qtrs (annual)

<u>HVAC/Refrigeration</u>:	
Bldg A/C units	806 Systems (monthly)
A/C start-up & PM	571 Sys - FH (annual) 184 Plants- nonFH (ann)
Refrigeration eq - water coolers - walk-in reefers	 399 units (quarterly) 48 Sys (quarterly)
<u>Interior Electric</u>:	
Emergency generators:	13 generators (weekly)
Auxiliary lighting:	15 Bldg (monthly) 80 Bldg (annual)
Electrical panels/safety switches	125 Bldgs (annual)
<u>Buildings & Structures</u>:	
Medical facilities PM	226K Sq Ft (quarterly)
FH Quarters PM	860K Sq Ft (quarterly)
Troop housing PM	2,166K Sq Ft (quarterly)
Other bldgs/structures PM	3,300K Sq Ft (120-day cycle)
Reserve centers PM	431K Sq Ft (semi-annual)
<u>Kitchen & Laundry Equipment</u>:	
Dining room support	20 Facilities (monthly)
Bldg kitchen eq - refrigerators - ranges/stoves	 2166 ref units 696 gas/192 elect (quarterly)
Barracks laundries	499 washers/505 dryers (monthly)

APPENDIX C:

PACER PROGRAM PERFORMANCE OBJECTIVES

OBJECTIVE 1: DEVELOP AUTOMATED COST ANALYSIS/REPORTING SYSTEM.

An Economic Analysis Program is needed by the Health Care Support Division (HCSD) of the Directorate of Engineering and Housing (DEH) at Madigan Army Medical Center (MAMC) for managing maintenance and preventive maintenance (PM) costs, and for performing cost-effectiveness studies of the developing PM Program. This program is to be installed on microcomputers with MAXIMO Maintenance Management Program; it is to work with MAXIMO and provide input/output to the general HCSD data base.

An evaluation of the transition in HCSD needs from preparation, startup, shakedown and operations modification to the eventual steady-state of firm operations indicates an Economic Analysis Program with the following capabilities:

1. Provides a method of determining the relative cost benefit of PM for installed equipment, and incorporates the capacity to store data for identifying improvement trends and for developing PM assignment rankings. (Cost benefit is defined here, initially, as the HCSD operations cost for supporting a unit of equipment with a complete PM package compared to the operations cost when not supporting the unit with anything but necessary repair and overhaul, thus incurring a loss of service penalty for every breakdown.)

2 Facilitates and encourages the collection of PM experience and available equipment statistics. The system identifies and accepts relevant inputs that build on the PM knowledge base.

3. Allows variation in computation methods. There is wide site-flexibility in defining and/or adding terms to needed computations. For example, for greater simplicity, HCSD overhead is not used in the Allocated Maintenance Cost (AMC) discussions to follow, but it easily could be included.

4. Performs economic analyses or makes best estimates based on the information and quality of data available; files these computations on request, and updates data base information from these files when the user considers this appropriate. From data base and user supplied information, a total PM Program assessment report will be generated on request.

OBJECTIVE 2: AUTOMATE THE PREFERENTIAL ORDERING OF PM TASKS.

List (order) MAMC equipment according to relative cost benefit (CB) ratings for the PM categories of HCSD-provided support. (Normally, operator-performed PM is not considered a part of this support.)

As a First Approximation, assume that the PM Program by HCSD does not allow unexpected dropouts, is free of major overhauls for the duration of the study, and is costed at a constant rate. Assume also that failure occurs at a known rate if the PM for a unit is not applied by the HCSD User, and that a TOTAL COST to the HCSD, the MAMC, and the Department of the Army (DA) of each failure can be estimated.

1. Net Present Value (NPV) Cost of a maintenance program (as expended over the duration of the economic study) can be allocated for the particular unit being evaluated. This is the Allocated Maintenance Cost of the unit or AMC (UNIT) and is defined as:

$$AMC(UNIT) = PM\ Cost + Maintenance\ Cost + On\text{-}line\ Repair\ Cost$$

2. The Penalty for not performing AMC(UNIT) is expressed as a Loss Of Service (LOS) charge each time a failure occurs:

a. The LOS for a single unit failure is defined as:

LOS(UNIT-FAILURE) = L&E for Removal/Overhaul/Replacement + Use-Cost of Alt. Systems + Allocated Dropout/Disruption Cost to MAMC Mission + DEH Loss of Goodwill Cost (damage that can result in lessened cooperation and operations constraints).

b. The NPV of the Aggregated Loss of Service (ALOS) for all failures of the unit over the time period of the study (N years) is defined as the ALOS(UNIT).

3. For the portion of equipment-unit operations cost (EUC) that varies with maintenance level, it may be shown that EUC = AMC(UNIT) + LOS(UNIT). If this equation is written for a PM-shop level of support (w/PM) and an operator-only PM support (w/o PM), we have:

a. EUC(w/PM) = AMC(UNIT w/PM) + ALOS(UNIT w/PM)

b. EUC(w/o PM) = AMC(UNIT w/o PM) + ALOS(UNIT w/o PM)

4. A present value cost benefit for performing PM on this Unit is based on what will not be spent because of the PM or maintenance performed by the PM shop. This may be stated as.

Cost Benefit of Unit PM =
[Total Operations Costs w/o PM(UNIT)] - [Total Operations Costs w/PM(UNIT)] = EUC(w/o PM) - EUC(w/PM).

It is reasonable to assume that a quality PM program will be able to better predict failures of the example unit and that failures will occur less frequently than under the minimal PM condition. Hence, LOS(UNIT w/PM) << LOS(UNIT w/o PM) and the NPV of this LOS will become very small as the mean time between failure, or MTBF(UNIT w/PM) approaches N years (the study limit).

For evaluating the cost benefit for the example unit [CB(UNIT)] as a first approximation it may be assumed that the NPV of the AMC(UNIT w/o PM) and LOS(UNIT w/PM) are very small and could cancel each other to leave:

CB(UNIT) ≅ [ALOS(UNIT w/o PM) + (negligible)] - [AMC(UNIT w/PM) + (negligible)].

Similarly, to determine the value of the complete maintenance program for the unit, compare the cost of Complete Support to the Cost of Only Failure Response:

CB(UNIT) ≅ ALOS(UNIT) - AMC(UNIT).

RELATIVE COST BENEFITS FOR UNITS IN A GIVEN CATEGORY CAN BE DEVELOPED IN THIS MANNER FOR TREND AND RANKING PURPOSES.

5. PACER graphs this estimation as follows:

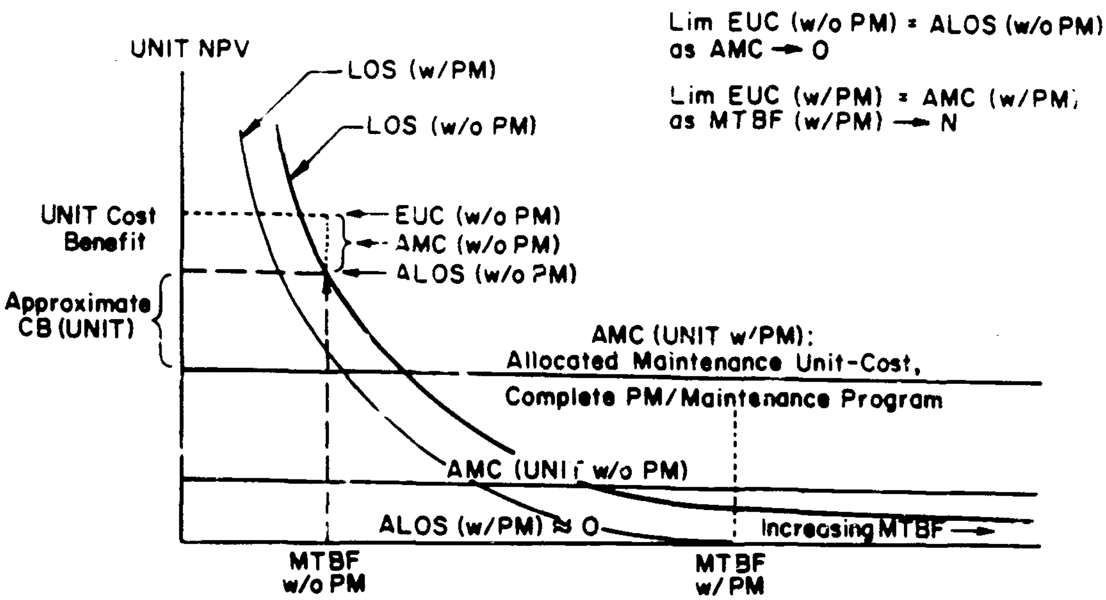


Figure B1. Correlation of the Net Present Worth of PM costs and LOS penalties.

OBJECTIVE 3: ASSIST ESTIMATION AND SCREENING OF COST DATA.

Provide guidance to the PACER user in keeping PM, AMC, LOS, and MTBF estimates or supplied values within reasonable bounds.

ASSUMPTIONS:

1. First Approximation assumptions of Objective 2 are also applicable here.

2. The MTBF of any MAMC unit of equipment will not be less than the period of the manufacturer's warranty. The MTBF of the unit with PM support will be equal to or greater than the period of the First-Estimation Run; the MTBF of the unit without PM Support will be equal to or less than the period of this initial study.

3. For a given MTBF, the LOS(UNIT) less the AMC(UNIT) cannot be greater than the cost of the unit. (If the LOS charge is excessive for a constant PM cost, a standby unit could be purchased.)

4. The allocated cost of the PM program in this First Approximation will be evenly distributed over the period of the study.

5. Once the HCSD user has become involved in the PACER estimation process, two factors will encourage a steadily improving data base. First, the user will be interested in data that improves his or her estimations. Second, the PACER Program will conveniently screen and accept submitted data base entries.

OBJECTIVE 4: FIRST ESTIMATES OF PM(UNIT) COST BENETIFS.

Apply computer programming techniques to assist in the estimation of a cost benefit for a particular unit using the reasonable value estimates of Objective 3.

The PACER Program will:

1. Run "what-if" or "for-the-record" relative PM CB Studies only at the equipment unit level (aggregate or system level cost benefit estimates are not recommended).

2. Group unit PM cost benefit entries into three operations or regulation areas, and label these areas; MUST to reflect essential or OSHA/hospital/EPA mandates; REQUIRED to reflect the unit/system support necessary to normal operations; and DESIRED to reflect support that facilitates effective operations.

3. Generate a Preferred Equipment List Report by ordering the PM tasks under the three labels of Item 2 according to the derived cost-effectiveness of each unit/system listed. This positioning in the HCSD PM Roster identifies the PM task priority by the estimated value of these tasks to the MAMC mission.

4. A selected economic evaluation report can consist of a Preferred Equipment List (Item 3) incorporating summations of the cost benefits of listed PM tasks that have been summed/developed into a cost-effectiveness rating for the entire HCSD PM program. Also, where the program value of a PM task is questioned, such reports/listings may be referred to for reevaluation or arguments for retention.

APPENDIX D:

COST BENEFIT PRESENT WORTH COMPUTATIONS

FORMULATIONS:

Present Worth, Uniform Series (PWUS) for an amount A in n years @ i interest:

$$PWUS = A \frac{((1+i)^n - 1)}{i(1+i)^n} = A\,(PWF)$$

Single Present Worth (SPW) for an amount A at a future date, m years hence:

$$SPW = A/(1+i)^m$$

ASSUMPTIONS: Interest i = 0.10

CASE 1:

Initial Cost: $25,000

PM:

Years: 1 - 5:	$300/yr		PWF(n=5) = 3.791
6 - 10:	375/yr		
11 - 15:	450/yr		
16 - 20:	525/yr		

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PW (1-5) = 300(3.791)/(1) = (1,137.0)/1 =	$ 1137
PW (6-10) = 375(3.791)/$(1.1)^5$ = (1421.6)/(1.61) =	882
PW (11-15) = 450(3.791)/$(1.1)^{10}$ = (1705.85)/(2.59) =	658
PW (16-20) = 525(3.791)/$(1.1)^{15}$ = (1990.0)/(4.18) =	476
PRESENT WORTH OF PM = PW(PM) =	$ 3153
PW(Overhaul) = 7K/$(1.1)^{15}$ = 7K/(4.18) =	$ 1676
INITIAL COST =	$25,000
CASE 1 TOTAL CHARGES =	$29,828

CASE 2:

Initial Cost: $25,000

PM:
Years: 1 - 20: $120/yr PWF(n=20) = 8.514

PW (1-20) = 120(8.514) = $ 1,022

Approximate Allocated Replacement Cost (ARC) @ 15 year mark:

Unit Cost in 15 years = $34,000.
PW(O'haul) = $6K(1.1)^8$ = 2,800.
Repayment Rate (RR) = 36.8K/15 = $ 2,453/year
PWUS (RR) for 5 years = 2,453 (PWF for 5 years)
= 2453(3.791) = $ 9,299.
ARC = PWUS(RR) + Removal & Installation Charges;
ARC = 9,299. + 4,000 = $ 13,299.

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PRESENT WORTH OF PM = PW(1-20) =	$ 1022
PW(Overhaul) = $6K/(1.1)^8$ = 6K/2.144 =	2799
PW(Replacement) = $13.25K/(1.1)^{15}$ = 13.3K/4.18 =	3184
INITIAL COST =	$ 25,000
CASE 2 TOTAL CHARGES =	$32,005

CASE 3:

Initial Cost: $25,000

PRESENT WORTH OF PM = PW(PM) =	0
PW(Overhaul) = $7K/(1.1)^5$ = 7K/1.61 =	$ 4345
PW(Replacement) = $33.5K/(1.1)^{10}$ = 33.5K/2.594 =	12,916
PW(Overhaul) = $7K/(1.1)^{15}$ = 7K/2.39 =	$ 1676
INITIAL COST =	$25,000
CASE 3 TOTAL CHARGES =	$ 43,937

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